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EAST AFRICAN FISHERIES RESEARCH ORGANIZATION
ANNUAL REPORT 1955/56

STAFF

Director	R. S. A. BEAUCHAMP
Fisheries Research Officer	P. H. GREENWOOD
Invertebrate Zoologist	P. S. CORBET
Fisheries Research Officer	D. J. GARROD
Hydrologist	VACANT
Malacology and Parasitology	C. C. CRIDLAND
Fishery Work, Maintenance of Boats, etc.	J. D. ROBERTS
Secretary	MRS. M. J. HARRIES
Assistant Secretary	MRS. E. CARTMELL

This report covers the period 1st July, 1955, to 30th June, 1956. As printing has been delayed for various reasons, reference should be made to certain important proposals put forward since the 30th June. Just after the close of the year a meeting of the Lake Victoria Fisheries Board was held at Entebbe on 26th July. At this meeting disagreement arose between the representatives of the three East African Governments on the subject of whether or not existing restrictions on fishing in Lake Victoria should be retained. This organization holds strongly to the view that the existing restrictions on fishing should be retained, Kenya holds similar views, but Uganda and Tanganyika were in favour of a proposal to lift these restrictions. This question was discussed a month earlier by the Director with the Colonial Office Fisheries Advisory Committee and they also advised the Lake Victoria Fisheries Board against lifting the restrictions.

The views of this Organization were presented to the meeting in a paper entitled " The Efficient Utilisation of the Fisheries of Lake Victoria." This paper is printed as Appendix " A " to this report.

Some changes have been introduced in the form of this report ; greater use has been made of Appendices as a means of recording results of work carried out by visiting scientists and other items of special interest ; accounts of studies made by members of the staff have been somewhat restricted, partly on grounds of economy and partly because many of these investigations are at the stage where they can only be recorded adequately as articles published in appropriate Scientific Journals.

The absence of a hydrologist during the past year has severely handicapped studies on the water of Lake Victoria. Nevertheless, valuable results have been obtained from the work of Dr. P. R. Hesse of the East African Agriculture and Forestry Research Organization who visited the laboratory for a period of three months. Dr. Hesse gave particular attention to the study of decomposition in bottom muds and to the distribution of sulphates in the water, aquatic vegetation and mud. The importance of sulphates in the production of aquatic plants and thus in the first link of the food-chain for all fishes, has been discussed in earlier reports, as has the anomalous behaviour of bottom mud in Lake Victoria. Since the natural manuring of lake water is ultimately dependant on the decomposition of bottom sediments, it is of prime importance that we should understand the factors controlling decomposition.

Dr. Hesse's results show that there are only traces of sulphur in the water, although there are large quantities in the bottom deposits ; but, since the rate of decomposition of these deposits is extremely slow, the sulphur is virtually unavailable to other organisms. The sulphur in the deposits is not, as was expected, present as sulphides but is in organic combination. In its natural state the water-logged bottom mud decomposes extremely slowly. However, if the mud is boiled, autoclaved, dried or even washed it decomposes more rapidly. A short account of Dr. Hesse's investigations is given in Appendix " B ".

A short series of observations on the hydrology of Lake Victoria was made by another visiting scientist Dr. J. F. Talling of University College, Khartoum. See Appendix " C ".

Data on the electrical conductivity of the head waters of the White Nile have been analysed. These have provided a method for estimating the relative contributions to the Nile of the three affluents, the Semliki River, Lake Albert and the Victoria Nile.

An important paper dealing with the chemistry and biology of papyrus swamps in Uganda was published during the year. This is the outcome of a visit to the laboratory by Dr. G. S. Carter of Cambridge University.

The results of field and laboratory studies on the distribution and seasonal flunctuations of snail populations in permanent and temporary bodies of water, will be published shortly. This work shows that the ability of snails living in small streams and pools to survive the dry season is inversely correlated with the degree to which they are infected by various parasitic trematodes. In permanent bodies of water the population size is also inversely correlated with the intensity of infection. Both these observations should have direct application as measures for controlling snails which may be vectors of Bilharzia and Liver fluke.

Observations have been continued on the life cycles of aquatic insects known to play an important part in the diet of fishes. In order to determine the patterns of emergence of adult insects, a mercury-vapour light trap was run for a hundred consecutive nights. Some thirty species, representative of several insect groups, have been identified and counted each night. The results are extensive and still wait analysis, but there are indications that several specie possess a lunar rhythm of emergence, whilst other species seem to emerge continuously and without any apparent indications of periodicity.

Using the mercury-vapour trap, collections have been made from various places around the shores of Lake Victoria. These collections have further extended our knowledge of factors limiting the distribution of several insect species.

The collection and identification of aquatic invertebrates is being continued, with the result that named collections of several groups are now available for reference at Jinja.

The correlation of larvae of aquatic insects with their respective adults continues and description of larvae have been and are being published.

Recent control measures carried out by the Uganda Medical Department against *Simulium* (mbwa fly) in the Victoria Nile have provided an opportunity to study the effects of D.D.T. on insectivorous fishes. Results obtained so far indicate that the various fishes are affected in different ways, see Appendix " E ". Some species for example, showed extreme adaptability and were able to utilize a wide range of insect food ; others, particularly Mormyridae, changed their feeding grounds to areas where the insects were protected against the full effects of the D.D.T. The fish affected most severely was the spiny-eel (*Mastacembelus victoriae*); this species proved unable to change its feeding appreciably and it seemed that many individuals either starved or were forced to leave the area.

Preliminary studies were made on the food of certain planktonic Crustacea. Such work has not previously been carried out on Lake Victoria and the results will help to fill an important gap in our knowledge of these animals, which form part of the diet in many fishes, see Appendix 'D".

Work on the food and feeding habits of piscivorous and insectivorous fishes in Lake Victoria, which was started in 1954, is now near completion. The stomach contents of over 9,000 fishes have been examined.

The outcome of these studies will be of great interest and value. For example, it is clear that both *Bagrus* and *Clarias* consume a greater proportion of fishes in their food than they are popularly assumed to do.

Work on the taxonomy and ecology of the seventy *Haplochromis* species in Lake Victoria is now virtually complete and a series of papers dealing with these fishes is in preparation ; two papers have already been published.

PUBLICATIONS

BEAUCHAMP, R. S. A. The Electrical Conductivity of the Head Waters of the White Nile. *Nature.*

CORBET, P. S. Larvae of East African Odonata 1. *Entomologist.*

CORBET, P. S. Larvae of East African Odonata 2-3. *Entomologist.*

CORBET, P. S. and TJONNELAND, A. The Flight Activity of twelve species of East African Trichoptera. *University of Arbok.*

CRIDLAND, C. C. Further Experimental Infection of Several Species of East African Freshwater Snails with *Schistosoma mansoni* and *S. haematobium. J. Trop. Med. & Hyg.*

CRIDLAND, C. C. Ecological Factors Affecting the Numbers of Snails in a permanent stream. *Trans. Roy. Soc. Trop. Med. & Hyg.*

CRIDLAND, C. C. Ecological Factors Affecting the number of Snails in temporary bodies of water. *Trans. Roy. Soc. Trop. Med. & Hyg.*

CRIDLAND, C. C. Ecological Factors Affecting the Number of Snails in permanent bodies of water. *Trans. Roy. Soc. Trop. Med. & Hyg.*

FISH, G. R. Chemical Factors limiting Growth of Phytoplankton in Lake Victoria. *E.A. Agric. J.*

FISH, G. R. Some aspects of the Respiration of six Species of Fish from Uganda. *J. Exp. Biol.*

GREENWOOD, P. H. The Monotypic Genera of Cichlid Fishes in Lake Victoria. *Bull. Br. Mus. nat. Hist. Zool.*

GREENWOOD, P. H. The Fishes of Uganda. Part II. *Uganda J.*

GREENWOOD, P. H. A Revision of the Lake Victoria *Haplochromis* species. (Pisces, Cichlidae). Part I *Bull. Br. Mus. nat. Hist. Zool.*

LOWE-MCCONNELL, R. H. The Breeding Behaviour of *Tilapia* species (Pisces-Cichlidae) in Natural Waters Observation on *T. karomo* Poll & *T. variabilis.* Boulenger. *Behaviour.*

LOWE-MCCONNELL, R. H. Observations on the Biology of *Tilapia* (Pisces-Cichlidae) in Lake Victoria, East Africa. *E.A.F.R.O. Supplementary Publication No.* 1.

MACDONALD, W. W. Observations on the Biology of Chaeborids and Chironomids in Lake Victoria and on the Feeding Habits of the "Elephant-snout Fish" (*Mormyrus kannume*). *J. animal Ecology.*

PUBLICATIONS BY VISITING SCIENTISTS

CARTER, G. S. The Papyrus Swamps of Uganda. *W. Heffer & Sons Ltd., Cambridge.*

HICKIN, N. E. Larvae of some East African Trichoptera. *Proc. R. ent. Soc. Lond.*

HICKIN, N. E. Larvae of some further East African Trichoptera. *Proc. R. ent. Soc. Lond.*

LEVRING, T. Light pentretion in some tropical African Lakes. *Oikos, Denmark.*

APPENDIX A

THE EFFICIENT UTILISATION OF THE FISHERIES OF LAKE VICTORIA

by R. S. A. Beauchamp (Director of E.A.F.R.O.)

This Memorandum is an attempt to describe the state of affairs relating to the fisheries of Lake Victoria. As this account may in certain respects appear to be confusing or may make tedious reading, it is perhaps desirable to start by summarising the opinions expressed. If confirmation for these opinions is required, a careful study of this memorandum should be made together with the analyses of the fishery records that are now available.

1. The single most important species of fish in Lake Victoria is *Tilapia esculenta.*

2. In certain areas all the ' other large species ' considered together may be of equal value to the *Tilapia.*

3. The smaller species constitute a fishery that remains largely unexploited.

4. The fishery rules for Lake Victoria were originally designed to protect *Tilapia.* They also afforded protection to the other fishes occurring in the Lake. Graham's original recommendations were never fully carried out and a modification to the original rules has been made which reduces the protection once afforded to the ' other species of fish ' both large and small. This modification was the legalising of nets with meshes of 3″ and under.

5. If greater use were made than is at present of 3″ nets and under, the yield of other fish could be increased without danger to the *Tilapia.*

6. The proposed lifting of restrictions on the use of nets between 3″ and 5″ will provide only a moderate increase in the yield of other fish but will provide a greatly increased yield of *Tilapia.*

7. This increase in yield of *Tilapia* will not last for long, perhaps three or four years.

8. After three or four years a decline in the total yield from all the fisheries will become apparent. This decline will be most marked in the *Tilapia* fishery.

9. In five or six years the total yield from all the fisheries will almost certainly be less than it is at present.

10. Irretrievable damage will by then have been done to the breeding stocks and the decline in the fisheries will continue.

11. The reimposition of restrictions (even if possible) would not restore the position to any appreciable extent.

12. Even if total prohibition of fishing were to be imposed (which is of course utterly impossible) it would take four or five years to restore the fisheries to their present state.

13. Apart from the increase in yield that can be expected from the use of 3″ nets and under, it is probable that the maximum *sustainable* yield is now being taken from the lake.

14. It is of paramount importance that the existing rules be maintained and enforced. The only way to make it possible to control the situation on the lake will be to register all dealers in nets and to control their import of nets.

There are at least one hundred and twelve species of fish in Lake Victoria, all of them are edible and could in one form or another be used as food for human consumption. The majority of these fishes inhabit relatively shallow water, in fact if one defines the inshore waters as the zone between the coast line and the eighty foot depth contour, it is probably true to say that 90% of all the fishes in the lake are contained in the inshore waters. The width of this zone varies considerably in different parts of the lake, being thirty miles wide in some areas and only a mile or two in others. The inshore waters are extensive in those parts of the lake where there are many islands and is restricted along some of the more exposed coast lines.

The species of fish which inhabit the exposed coastlines are different from those which inhabit the more sheltered and indented shorelines, and the species that live close inshore are different from those which occur in somewhat deeper water. More important still is the fact that species which occur in a variety of habitats, have definite habitat preferences so that their relative abundance differs according to the habitat. Some species have a restricted distribution, but many during the course of their lives range over a wide variety of habitats, yet are typically more abundant in particular regions at certain stages in their life histories.

Bearing the above facts in mind, it is obvious that the number and species of fish caught in particular types of net will vary according to whereabouts in the lake they are set. It is therefore difficult to assess quantitatively the relative abundance of the various species which together make up the total fish fauna. It is also evident that fishing methods and fishing gear which may be suitable for one part of the lake may not be the best for another area, and from this it follows that fishing regulations should *ideally* be varied to suit particular topographical areas within the lake.

The great difficulty to be overcome when forming fishery legislation for Lake Victoria is to design a set of rules that are not too complex and which when applied *throughout the lake* may be expected to crop the lake in such a way as to give the maxum sustained yield, composed of fish belonging to as many species as possible.

Quite apart from any question of the extent to which any set of rules may be evaded, the efficacy of these rules will depend very much on the way they are implemented by the fishermen. When several types or sizes of gear are permitted, fishermen may prefer one type or size and rarely use another, thus defeating certain of the aims of the legislator. Such preferences are apparent among the fishermen on Lake Victoria. The majority rarely use, and then only in certain areas, gill nets of 3″ mesh or under although these nets are legal gear and may be used in any part of the lake. The next largest size that is permitted is the 5″ net and this is the net in general use.

These 5″ nets are set primarily to catch *Tilapia* and this preference by the fishermen may be taken as an indication that the *Tilapia* fisheries are to them of greater value than the other fisheries. However this question of the relative value of the various fisheries needs to be considered more objectively.

When assessing the commercial value of a fishery several points need to be considered ; first among these is the abundance of the fish concerned, and their abundance should ideally be determined before exploitation. Individual lakes provide particular conditions which favour certain species, thus a lake may aptly be described as a trout lake or a carp pond ; trout and carp being the dominant species present in the two types of lake respectively. Lake Victoria should in such terms be described as a cichlid lake. as cichlid species of fish (*Tilapia* and *Haplochromis*) are undoubtedly the most abundant. This assessment holds good whether abundance is determined in terms of numbers or of total weight of fish. It may be questionable whether at the present time any one species in the lake can with certainty be named as *the* dominant fish, but among those species which might be so described, *Tilapia esculenta* (the Ngege) is even now a likely choice ; previously at the beginning of the century this fish was far more abundant than it is now, and probably in those days one would have had little hesitation in deciding it as the dominant and most characteristic fish in the lake.

Tilapia variabilis is not as common as *T. esculenta* (except in certain areas), however if these two species are considered together it is entirely reasonable to describe Lake Victoria as a *Tilapia* lake.

Amongst other points to consider when assessing the commercial value of a fish are the following : the size to which they grow and the proportion of their bodies that is edible (ratio of flesh to bones, head, etc.) and their ecological position in the general economy of the lake. Under all these counts the *Tilapia* must be classed as very valuable fish. The last point raised, namely their ecological position, is by no means unimportant ; as both species are phytoplankton and algal feeders, they play a fundamentally important part in determining the fertility of the lake, their own abundance and the abundance of other species of fish. Therefore *Tilapia* must be considered as fishes of the greatest importance to the commercial fisherman.

The other cichlid fishes occurring in Lake Victoria are the *Haplochromis* group. These fish do not match up to the *Tilapia* in commercial importance because of their small size ; they nevertheless are extremely abundant and form a valuable source of food, which unfortunately remains largely unexploited, though in certain areas (Sesse Islands) the fishermen take the trouble to catch them using suitable small meshed gillnets, and in other areas along exposed coastlines they are taken in seine nets.

After the Cichlids the next most abundant fishes in the lake are probably the Mormyrids, notably *Mormyrus kannume*, the elephant snout fish, which feed mainly on insect larvae. These fish remain largely unexploited, partly because there is a prejudice against eating them and partly because they occur most abundantly in moderately deep water, though still within the limits of the inshore waters as defined above. (Two attempts under European supervision have been made to harvest these fish, but both have failed for various reasons.)

The next most valuable fish is probaly *Labeo* (Ningu) a widely distributed detritus feeder. After the Ningu in importance come various predatory fishes, *Schilbe*, *Bagrus* and *Clarias*. None of these fish are generally abundant though they occasionally occur in large numbers in certain areas.

Protopterus (Lungfish) form a significant element in commercial catches and could in certain areas withstand further exploitation by long-lining.

Barbus are only important commercially during short seasons, and then only in particular areas, especially rivers.

This account of the fisheries given very briefly and in terms of their relative abundance and commercial value is an attempt to indicate roughly the potentialities of these various fisheries. The question remains how best can this complex of fisheries be utilised.

All these fishes, with the possible exception of the Lungfish, can best and most economically be caught with gillnets. Trawling is not really an economic proposition and only in certain areas are seine nets both practicable and permissible. Seine nets can only be used where there are suitable beaches ; such beaches occur infrequently over much of the coastline, the greater part of which is overgrown with swamp vegetation. Furthermore it is now generally agreed that in sheltered areas where there happen to be suitable beaches, seine nets should not be used because of the damage they do to the *Tilapia* fisheries. Thus the use of these nets is limited by the physical condition of the shoreline and by agreed legislation.

Given that gill nets must be the principal instrument for catching the different kinds and sizes of fish occurring in the lake, there remains to be decided the ' question ' whether or not the existing regulations regarding mesh sizes are the best that can be devised.

It is obvious that gill nets select fish according to their girth measurements and on these measurements *Tilapia* must be classed among the larger species occurring in the lake. The usual practice, when considering control measures based on the size of mesh, is to prohibit the use of small meshed nets which may catch immature fish. It would therefore seem that a policy designed to protect *Tilapia* must inevitably conflict with any policy aimed at catching any of the other smaller fish. The acceptance of this concept in a somewhat uncritical way has probably led to the generally held belief that the present day legislation on Lake Victoria is designed solely in order to afford a measure of protection to the *Tilapia*. This belief probably originates from the fact that Graham, after his survey in 1928, advocated just such a policy, that is to say a policy aimed primarily at protecting the *Tilapia*. He concluded that commercially these fish were by far the most valuable and should be protected. Incidentally his opinion that the *Tilapia* were the most valuable fish in the lake should not be lightly ignored, particularly as it was formed at a time when the lake had not suffered so severely at the hands of the fishermen as it has now.

Graham recommended that all nets capable of taking small-sized Ngege should be " eliminated " and that steps should be taken to restrict the fishery to the 5″ net alone with an exception in favour of the seines. His recommendations were not however fully implemented and the $2\frac{1}{2}$″ (Ningu) net continued in use. Studies carried out by E.A.F.R.O. and some experimental fishing undertaken later by the Lake Victoria Fisheries Service have shown that nets of 3″ mesh and under may be used without endangering the stocks of young *Tilapia* ; this is due to the particular habits of these fish.

The habits of the *Tilapia* have by now been described many times and the fact that they brood their eggs and young in the mouth and retire to the swampy margins of the lake to do so, is now well known. It is perhaps less well known that the young fish tend to remain close to the weedy shore line until they have grown fairly considerably. Whilst living among the weeds they cannot be caught in gill nets which have to be set in open water. After a while the young *Tilapia* move on into more open water, but by this time they are usually too big to be caught in nets of mesh less than 3″. Once this was fully established the use of gill nets of 3″ mesh and under was encouraged and permitted even in areas, (e.g. the Kavirondo Gulf) where previously they had been forbidden.

Nets of 3″ mesh and under can be fished with success in most areas of the lake and they catch a great variety of species : *Labeo*, *Haplochromis*, *Mormyrus*, *Schilbe*, *Synodontis*, *Bagrus* and *Barbus*. (*Clarias*, though widely distributed, appears not to be a common fish and is rarely caught in these nets. However records of *Clarias* caught in gill nets may be misleading as these fish on account of their shape are not readily caught in gill nets.)

It must be appreciated that allowing the use of 3″ nets and under has entirely changed the nature of the mesh regulations as originally formulated by Graham and it would be wrong to suppose that no thought has been given to the need to capture fish other than *Tilapia*. In fact under the existing rules almost every species of fish in the lake can be caught legally in gill nets, and no species are fortuitously protected to any significant extent because of legislation framed to protect the *Tilapia*. The rule prohibiting nets of mesh between 3″ and 5″ besides giving protection to the *Tilapia* does give some protection to some species of ' other fish ', but it must be remembered that the young of these species can be caught in the 3″ nets. The present rules only afford a significant degree of protection to the *Tilapia* because when they are young they are inaccessible and do not get caught in the under 3″ nets.

If the fishermen were to be allowed to use nets of mesh sizes between 3″ and 5″ they would catch large numbers of *Tilapia* and many of these would be immature. The ratio of immature to mature fish in the catches is naturally higher the smaller the mesh of the nets used. Records of the average catch of fish from nets ranging in size from 3″ to 5″ are presented separately. It can be seen that in some areas for every ten *Tilapia* caught in 4″ nets only about three ' other fish ' are likely to be caught. These figures may serve as an indication that the use of 4″ nets is not likely to produce in all parts of the lake a considerable yield of ' other fish.' There are, of course, certain areas for example in the neighbourhood of Dagusi Island where E.A.F.R.O. discovered Mormyrus grounds where good catches of these fish can be made with 4″ nets, and there are a few areas along the more exposed coastlines where the yield of ' other fish ' relative to the yield of *Tilapia* may be reasonably high. However, if the lake is considered as a whole it is quite certain that the catches made in the over 3″ nets will consist mainly of *Tilapia*.

In order to assess the probable effect of relaxing the prohibition on nets between 3″ and 5″ one must try and visualise first what the *Tilapia* population was like before it was exploited and secondly in what respects, as regards both to density and composition it has changed since the introduction of imported nets. We know that at the beginning of the century the catch per unit of *Tilapia* was very high. Catches as high as two or three hundred per net are on record, and there is little doubt that the average catch was considerable. At a later date evidence from Graham's survey shows that in 1928 the 5″ net caught more fish than did the 4″ net. Quite the reverse obtains today ; now the average catch per net in the 4″ net is considerably higher than the average catch per net in the 5″ net. These records considered together with the apparently very low mortality rate of *Tilapia* after they reach sexual maturity leads one to believe that under natural conditions (pre-exploitation days) Lake Victoria contained not only vastly greater numbers of *Tilapia* but a much higher ratio of old to young fish than at the present time. Excluding fry, mature fish probably outnumbered ' juvenile ' fish. This is an unusual conception for the composition of an animal population, but such a ratio of elderly individuals to younger individuals is a logical consequence, if the normal life span of the animals is long enough and if factors liable to cause death become fewer the larger (or older) the animal grows. (Death from old age, of course ultimately supervenes.)

Considerations must also be given to the fact that the older *Tilapia* grow at a slower rate than do the younger fish. The change to a slower growth rate occurs at the time when these fish become sexually mature at a total *length* of about 24 cms. At this size they are probably about three years old.

The 5″ net was selected as the minimum legal size of net as this net normally only catches fish over 27 cms. long (total length). At this size these fish are probably about four years old. They have therefore had about a year (or longer) in which to breed before there is much risk of them being caught.

The 5″ net normally catches fish up to 33 cms. long, larger fish may also be caught occasionally in these nets. At 33 cms. these fish are probably nine or ten years old. In the early days when gill nets were introduced 5″ nets were capturing stocks of fish which represented the sum of at least six years current production.

These stocks of older fish are sadly depleted ; it is now more usual to catch fish belonging to the lower half of the size range 28-33 cms. than to the upper half, and the catch per net is down to two or less. At the present time most of the fish being caught in the 5″ nets are recent recruits into the size range caught by these nets. In the more intensely fished areas the total annual yield of fish is probably of the same order as the annual rate of recruitment.

Much has been written, which need not be repeated here, to show that the production rate in Lake Victoria and in other tropical lakes is lower than at first might have been imagined. The abundance of fish, notably *Tilapia,* in some tropical lakes has led people to think that the annual production rate must be high. Actually the annual production rate may be low, and yet fish may be abundant because surviving off-spring from several successiye vears have been able to accumulate. This explanation for the abundance of fish in some tropical lakes could have been more obvious if the age of these fish could be determined readily.

All the evidence we have, shows that in about thirty years 5″ gill nets have reduced the accumulated stocks of 5″ fish from a high value to an extremely low value and we are now dependent mainly on recent recruits to this size group.

We should now consider the stocks of fish which supply these recruits, namely those fish which are caught in 4″ nets. All our present records show that these fish are far more abundant than the 5″ group. The 4″ fish, range in size from 23-28 cms. (total length) and range in age from two and a half to four years, or possibly from two to four years. From this it may be seen that the stocks of 4″ fish represent no more than two years production.

If it has taken about thirty years to deplete the stocks of 5″ fish, composed as they were of at least six year groups, it can be anticipated, bearing in mind the intensity of the fishing effort at the present time, that it will take considerably less than ten years to deplete the stocks of 4″ fish and this estimate takes no account of the damage done to the breeding stock.

As explained above the size range of *Tilapia* caught in 4″ nets extends below the minimum breeding size. Thus the use of these nets will progressively deplete the *last remaining reserves of breeding fish.* The effect of this will become apparent in about two and a half to three years, i.e. the time it takes a *Tilapia* in Lake Victoria to reach sexual maturity from hatching. So after a period of say three years, not only will the stocks of 4″ fish be reduced to about half their present numbers, but the reproductive potential will be similarly reduced. When one considers the progressive deterioration that is likely to follow, it is probably no exaggeration to say that in the more intensely fished areas of the lake, the use of 4″ nets will reduce the *Tilapia* fishery to negligible proportions in a matter of five or six years.

Summarising the above opinions, it seems that lifting the restrictions on the use of nets of mesh between 3″ and 5″ will produce over a period of about three years a considerable numerical increase in the yield of *Tilapia* and a slight increase in yield in ' other fish ', but after three years a rapid decline in the total annual yield must be expected and this yield is likely to fall to values below present values in under seven years After only five years of unrestricted fishing the damage caused in some areas may be such that no practical restrictions could be imposed which would be severe enough to allow the *Tilapia* fishery to recover. It must also be appreciated that damage will also be done to the other fisheries.

The difficult position in which the Chief Fishery Officer of the Lake Victoria Fisheries Service finds himself is fully appreciated. At present every type of both legal and illegal gill net can be purchased from any dealer without restrictions of any sort. The fishermen in many parts of the lake now ignore regulations as fishing with the 5″ net is becoming uneconomic, and they know that by using $4\frac{1}{2}$″ and 4″ nets they can make a profit. Many of them realise that their behaviour is unwise, but if one fisherman uses illegal gear it is only natural that others should rapidly follow suit. Under these circumstances it is quite impossible for officers of the L.V.F.S. to enforce the existing fishery rules.

There would seem to be only one way to restore the position and that is to require all dealers in nets to be registered and to institute without delay a system whereby the total import of nets of various mesh can be controlled and their distribution regulated according to the requirements in different parts of East Africa. No doubt there are many difficulties to be overcome, both on account of the fact that nets that are illegal on Lake Victoria are legal elsewhere and because ' the trade ' may offer a stout resistance to being restricted. But unless these difficulties are overcome and the fishery rules enforced it must be realised that the fisheries of Lake Victoria are likely to be reduced to values below existing levels in a very short time, and these fisheries may only be saved from virtual extinction by the relentless law of diminishing returns.

If adequate alternative sources of food were available, one might argue that a policy of laissez-faire was, for political reasons, justifiable, but no such sources of food are likely to become available in the near future.

June, 1956.

APPENDIX B

THE DISTRIBUTION OF SULPHUR IN THE MUDS, WATER AND VEGETATION OF LAKE VICTORIA AND ITS FIXATION IN THE BOTTOM DEPOSITS

by P. R. Hesse

E. A. Agriculture and Forestry Research Organization

As the growth of algae cultured in water from Lake Victoria is limited by the shortage of dissolved sulphates (Fish, 1956) and as algae form the main food of *Tilapia*, it was obviously desirable that a chemical survey on the distribution of sulphur within the lake should be undertaken.

It had been assumed that the sulphates biologically removed from the water in the formation of plankton and other vegetable matter, were ultimately reduced to insoluble sulphides which accumulated in the lake bed. It was discovered however (Hesse, 1956) that although sulphur is indeed present in large quantities in the bottom deposits of the lake, it is not in the form of sulphides but in organic combination. Even at depths of 15 metres below the mud surface less than 4% of the total sulphur present is in the reduced form.

As previously observed the lake muds show little tendency to decompose. It was considered therefore that the most important single factor limiting the fertility of the lake was probably the slow rate of decomposition of the bottom deposits, so a series of experiments were carried out to determine the rate of decomposition of the muds and to investigate the factors affecting such decomposition.

A subsidiary issue affecting the liberation of sulphur from bottom deposits is the fixation of sulphate as such by the mud. It was found that although the top 3 cm. of mud in Pilkington Bay contained over 70 p.p.m. of sulphate, extractable by Morgan's reagent, the lake water filtered from the mud contained no sulphate. It was at first thought that this phenomenon was due to sorption of sulphate by ferric complexes in the oxidised surface layers of mud. That such sorption processes can occur in oxidised muds has been demonstrated by other workers notably Mortimer (1941) who showed that if such muds were kept under anaerobic conditions the ferric complexes were destroyed and the sorbed ions liberated. Experiments, similar to those of Mortimer, using Lake Victoria muds did not, however, give the expected results.

After confirming that the muds in their natural state decompose at an extremely slow rate, further experiments were carried out, which led to the following conclusions—

1. Filtering off the excess water and permitting the muds to decompose aerobically slightly increases the rate of oxidation and during the course of the decomposition the sulphate content of the mud is increased.

2. Mud, decomposing under lake water, loses sulphate and although no explanation for this has yet been established, it is tentatively suggested that this is due to the assimilation of sulphates by micro-organisms.

3. Certain treatments of the muds profoundly affect their subsequent decomposition. Either boiling, autoclaving, oven-drying or washing the muds with Morgan's reagent accelerates the initial rate of oxidation.

4. Although a fresh, waterlogged mud produces no sulphide during its decomposition, a mud treated by one of the processes described above in para. 3, does produce sulphides, which then become fixed by the iron and manganese present.

Sorption of sulphates

It was found that keeping muds under anaerobic conditions for a period of eight weeks did not cause the liberation of sulphate ions although the overlying water was completely deoxygenated and all the ferric ions were reduced to ferrous. This experiment indicated that the lack of exchange of sulphate between the mud and water is not due to sorption by ferric complexes. Other experiments revealed the fact that whereas sulphate originally present in the muds was not reduced to sulphide, added sodium sulphate was reduced.

If ferric complexes were responsible for the sorption of sulphates then treatment of the muds with such compounds as Alizarin-S or 8-Hydroxquinoline (oxine), which form insoluble compounds or stable chelates with ferric ions, should prevent or reduce such sorption. Experimental evidence clearly showed that no such ' blocking ' effect occurred and confirmed that the ferric complexes are not responsible for the fixation of sulphates, or at least have a minor effect.

It was found that the mud from Thruston Bay did not exhibit the same sorptive properties as that from Pilkington Bay ; for example, Morgan's reagent extracted over 70 p.p.m. of sulphate from Pilkington Bay mud, but Thruston Bay mud yielded only 10 p.p.m. It had already been noted by Beauchamp that the silica fraction of the two muds possessed different characteristics. That from Thruston Bay was chiefly in the form of sand whereas that from Pilkington Bay was mostly accounted for by diatom frustules. If the seat of sulphate sorption was located in the diatomite of Pilkington Bay the observed facts would be explained. That is, we would expect the mud of Thruston Bay to sorb little sulphate compared with that of Pilkington Bay and furthermore, neither anaerobic conditions nor treatment with oxine would affect such sorption. From further experiments, using the muds from both bays and a sample of pure diatomite, it was concluded that the presence of large amounts of diatomaceous silica is the most likely cause for the sorption of sulphate.

Conclusions

The rate of decomposition of the bottom deposits is probably the most important factor affecting the fertility of Lake Victoria. Experimental evidence has indicated that organic sulphur, deposited on the lake bed in the form of plant debris, has little chance of being converted into available sulphates. Where diatom frustules account for most of the silica in the muds, part of the sulphate present is adsorbed and, in such cases, not only is it withheld from solution but it is protected from reduction.

The higher plants growing in the lake contain ample sulphur.

The soils on the islands in the lake are well-leached of sulphur, except where patches of forest conserve it or, where as on Yempaita Island, it is held by an impervious layer of rocky material.

Very little sulphur (less than 1 lb. acre/annum.) is supplied to the lake via the rain.

Detailed analytical results for water, muds, vegetation and soils are being published together with descriptions of all the experiments carried out.

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APPENDIX C

SOME OBSERVATIONS ON SEASONAL AND DIURNAL CHANGES OF STRATIFICATION IN LAKE VICTORIA

by J. F. Talling,

University College, Khartoum.

Stratification in the open lake

Work on the open lake during April and May was a continuation of earlier records taken in March by E.A.F.R.O. During most of March and April a relatively strong thermal stratification was found in the lake, similar to that described by Fish for the year 1953. A conspicuous discontinuity existed within the depth range 40-60 m. and below this discontinuity there was a shallow layer of water containing little dissolved oxygen. The depth interval occupied by the cooler deoxygenated water varied, suggesting an internal seiche in the lake basin similar to that described by Fish. The absence of stratification at the station on March 1st was probably caused by an extreme tilting of the water layers. A similar effect may have contributed to a later loss of stratification during early May, when cooling of surface water was also involved. During 1953 marked thermal stratification was also lost in May and did not reappear until much later in the year. In both 1953 and 1956 a maximum heat content of the water column was reached in March-April. In general the stratification found in 1956 was similar to that for 1953, and showed only minor differences in the timing of events.

The vertical distribution of planktonic algae was studied under conditions of both strong and weak thermal stratification. During the strong stratification of late April only one important alga, *Melosira nyassensis var. victoriae*, showed a maximum concentration in the lower, oxygen-deficient layer. Other species examined were poorly represented in this layer and showed maxima near the surface or in middle depths. It seems likely that these differences between species arise from differences in sinking rates and in their ability to withstand the conditions obtaining in the lower deoxygenated layer.

Shortly after these observations, in early May, a transition to an almost unstratified condition occurred at the station. As expected, this change led to a more uniform vertical distribution of the phytoplankton, and many species appeared in numbers in the lower layers. However, at least two species (*Ceratium brachyceros* and *Botryococcus braunii*) showed a marked preponderance in the upper layers. The *Melosira* population was still largely in the lower layers, although the total population in the water column had increased, suggesting a resuspension of cells previously resting on the mud surface. This change is also in agreement with the previous work by Fish at the same station.

Stratification in a shallow bay

During April 12-14 the stratification at a station, eight metres deep, in Pilkington Bay was followed for forty-eight hours. The main object of this work was to follow diurnal changes in oxygen throughout a water column in which diurnal changes of thermal stratification were prominent. These measurements could then be used to give an estimate of the daily value for photosynthesis per unit area, and a comparison made between this and an independent estimate derived from experimental measurements of photosynthesis at various depths. Comparison was also made with the results of similar studies on the White Nile near Khartoum.

The observations coincided with onset of cooler weather, which caused an interesting transition from a relatively strong thermal stratification on April 12, through a very weak stratification on April 13, to an unstable inverse stratification on April 14. These successive types of thermal stratification, which were interrupted by isothermal conditions at night, were closely connected with changes in the stratification of oxygen. Diurnal changes in oxygen content per unit area were about 4 g./sq. m., and a primary photosynthetic production of about 7 g/sq. m./day was estimated. This value is considered to be a fair estimate of the order of primary production in the Bay, and is high when compared with estimates from other waters.

Experimental measures of photosynthesis gave an estimate of primary photosynthetic production of 4.3 g./oxygen/sq. m./day. Although lower than the above estimate it also indicates a productive water. These experiments and other measurements of light penetration showed that the photosynthetic zone was about 6 m. deep in Pilkington Bay and about 20 m. deep in the open lake. They also gave some information on the photosynthetic characteristics of the algae (mainly *Melosira*) involved. Light saturation for photosynthesis commenced at light intensities comparable with those recorded from similar experiments in warm temperate waters, but the maximum photosynthetic rates—calculated per unit cell volume—were unusually high. Similarly high rates were previously found in experiments on the White Nile.

Full accounts of this work are in preparation.

APPENDIX D

THE PLANKTONIC CRUSTACEA OF LAKE VICTORIA

by J. Rzoska

(*University of Khartoum*)

Thirty years after the discovery of Lake Victoria by Speke (1858) the first plankton collections were made by Emin Pasha and Fr. Stuhlmann. Stuhlmann published two interim reports on his activities (1888, 1889) and a short note in 1891 on the plankton of the " South Creek " (probably Mwanza bay). Material collected by him was worked out by specialists. W. Weltner (1891) gave an account of the Cladocera; later he followed up with a list of Cladocera from Africa and especially Lake Victoria and the Nile Valley (1898). A. Mrazek (1897/8) dealt with the copepods of Stuhlmann's samples.

The next author was E. V. Daday (1907), who reviewed previous efforts and based his own investigations on material collected by A. Borgert in 1904-1905, during an expedition supported by the Berlin Academy ; stations named were Bugaia, Entebbe, Port Florence and Rusinga In the same year he published observations on the post-embryonic development of *Caridina wyckii* (=*C. nilotica*) which occurs in the plankton. At the same time, A. Cunnington collected during his third Tanganyika expedition a few samples from Lake Victoria and G. O. Sars examined critically the copepods and ostracods in this collection (1909). Daday (1910) in a paper on East African Microfauna published a list of all invertebrate groups from Lake Victoria.

A Russian expedition, led by Dogiel and Sokolow, collected samples of plankton; six of these came from the lake and were described by G. Verestchagin (1915), One plankton sample from near Bukoba formed the basis of a paper by Th. Delachaux (1917) ; this paper also includes some critical remarks on the taxonomy of certain Cladocera. Short references to planktonic Crustacea from the lake, collected by S. R. B. Pask, can be found in a paper by R. Gurney (1928) dealing with Tanganyika copepods.

E. B. Worthington (1931) studied diurnal vertical migration of the larger Crustacea in an open station in the north-eastern part of the lake in 1927 and compared these with similar observations in Lake Lucerne. Some references to the planktonic Crustacea may be found in the reports of the East African Fisheries Research Organization, Jinja.

This ends the list of accessible, published material, on the subject. Thus, although the planktonic Crustacea of Lake Victoria have been listed, a taxonomic revision is necessary. Moreover, the variability occurring among these organisms has not been critically studied and almost nothing is known about the ecology of the principal species.

In April 1956, J. Rzoska worked for a month at Jinja. His initial task was to investigate the food of copepods ; soon, however, he found that a taxonomic revision of all available records on the planktonic Crustacea was necessary as a basis for any future work.

Many " new " species have been described without taking into account variability due to their physiological condition. H. Gautier has shown in his study on *Moina* (1954) how important this may be. The copepods have been studied for many years by F. Kiefer and more recently by K. Lindberg ; morphometric methods on large samples as applied by Kozminski and by Rzoska to the group of species centred round *C. strenuus*, would be of great value.

Remarks on particular species.

Diaphanosoma excisum Sars, was first mentioned from Lake Victoria by Weltner (1897), who gave notes on some morphological details. Ekman (1903) found this species in the Nile valley, but the temperate *D. branchiurum* was found in Egypt by Richard in 1895. There are indications of great morphological variability in *D. excisum* over the vast circum-tropical area of its distribution (see Brehm in his study of Indonesian Cladocera (1933). This species is a very important constituent of the Nile plankton as revealed by recent sampling.

Ceriodaphnia cornuta Sars and *C. rigaudi* Richard. The controversy on the validity of the two " forms " has lasted for more than half a century, but their separation into two species can no longer be considered valid. Rzoska (in press) has shown the instability of the morphological characters regarded previously as distinctive. This species should, in accordance with priority rules, be called *C. cornuta* Sars, although the name does not fit the unhorned phase. This species is a tropical cosmopolitan ; the causes of variability and their trend should prove interesting. The species is an important constituent of open lake plankton in Lake Victoria.

Ceriodaphnia dubia Richard was noted by Daday (1910) as frequent in the lake plankton. Delacbaux records this species as *C. reticulata var. dubia.* This is a less consistent constituent of Lake Victoria plankton than the previous species ; it is widely distributed in the tropics but almost nothing is known about its ecology.

Other forms of *Ceriodaphnia* have been recorded from the lake ; Weltner (1897) lists a *Ceriodaphnia* sp., already noted by Stuhlmann, which is impossible to identify. Verestchagin recorded in his very limited material *C. laticaudata* P.E.M. and *C.quandrangula var. hamata* Sars which cannot be confirmed.

Moina dubia de Guerne and Richard has been recorded under various names as an important constituent of Lake Victoria plankton. H. Gautier (1954) has given an admirable analysis of some African *Moina* and it emerges that the morphology of this species depends upon environmental conditions and its physiology ; in spite of its variability there are, according to Gautier, only two definable subspecies of *M. dubia* in his African material. *M. dubia dubia* and *M. dubia pectinata,* of which the former is widespread in the plankton of African waters and the latter confined at present to Madagascar.

The following have been named from Lake Victoria : *M. brachiata* O.F.M. by Stuhlmann from the Mwanza region ; Weltner who had Stuhlmann's material did not confirm this find. Daday (1910) regards it as an erroneous identification. *M. micrura* Kurz was named by Weltner (1897) from a sample near Djuma island. *M. hartwigi* was found by Verestchagin in the plankton and he expresses surprise because this *Moina* is a littoral and pond form in temperate regions. Other authors note correctly that the Lake Victoria *Moina* is *M. dubia*; Delachaux gives some morphological details. *Moina dubia* is an important species in the lake, its ecology and physiology should be of great interest.

Bosmina longirostris O.F.M. has been recorded from the lake by various authors, sometimes under names of varieties whose value is not recognised adequately. This cosmopolitan species is very variable but some varieties have been established without a thorough critical analysis. Weltner (1897) described *B. stuhlmanni* from Lake Victoria, which Daday (1910) regards as synonymous with *B. longirostris* O.F.M. var. *similis* Lillj. Daday (1910) names *B.l. cornuta* and *B.l. longirostris* as not occurring in the plankton of Lake Victoria. Delachaux, however, records *B.l. cornuta* Jurine as the commonest planktonic form in the lake, and thinks that Daday's var. *similis* may be a seasonal variation. At present the problem of racial differentiation remains unsettled. This species is a consistent component in Lake Victoria plankton.

Chydorus sphaericus O.F.M. has a world-wide distribution, again with morphological variability ; Daday (1907 and 1910) and Delachaux remarked on differences between European and Lake Victoria specimens. Fairly numerous in the plankton.

Daphnia longispina Leyd. was seen by Weltner (1897) in the lake and differences from the " typical " form were mentioned. Delachaux names his specimens *D.l.* var *hyaline ;* other authors do not mention any variety. Worthington stresses the lack of long spines and helmets and also the lack of epphippial females ; however, the problem of racial and physiological differentiation requires further study. It is not true that sexual processes in the Cladocera are rare in the tropics. Woltereck (1930) has contributed to the geographical and racial differentiation of *Daphnia* species.

Daphnia lumholtzi Sars occurs in the plankton and was found by Daday. Distribution of this species is mainly in the Middle East, the eastern Mediterranean and southern Russia ; in the Nile valley this species penetrates deeply into Africa.

Daphnia barbata (Weltner) was first described from Lake Victoria by Weltner in 1897 under the name *D. jardinei* Baird *nov. var. barabta* and he recorded also epphippial females and males. Later its validity as a distinct species was recognized ; it seems to be a predominantly African species which has migrated down the Nile.

Simosa (*Simocephalus*) *vetulus* O.F.M. occurs locally as a conspicuous member of the plankton ; it was recorded as *S. capensis* by Weltner. There seems to be no mention of observed morphological differences from the typical European form. All other Cladocera mentioned by various authors are not truly planktonic species; they occur occasionally in the pelagic zone but not as permanent inhabitants.

The copepods are treated according to the systematic arrangement proposed by F. Kiefer (1928).

Tropocyclops (*Prasinus*) *confinis* Kiefer. This is the nearest determination possible at present for the form found in the Jinja area of Lake Victoria, though the specimens examined do not completely conform with the descriptions, drawings and two keys by Lindberg (1955a and 1955b). Mrazek (1898) mentioned *Cyclops prasinus* Fischer in Lake Victoria as " one of the most characteristics forms of the Copepod fauna of Africa ", Daday recorded it without making any detailed remarks. Sars (1909) mentions a pelagic form, *Cyclops tenellus*, from the plankton of Lake Tanganyika, but remarks that it does not occur in Lake Victoria. *Cyclops prasinus* represents a group of forms (22 in Lindberg's last key) which is distributed over temperate and tropical regions of the world, but occurs more abundantly in the warm water regions. In Lake Victoria it seems to be a regular member of the plankton of bays and inshore stations and occurs rarely in the open lake.

Mesocyclops leuckarti Claus is a cosmopolitan species which shows less variability, yet even the first observer noted that the Lake Victoria specimens differed from the European forms (Mrazek 1898). This is an important member of the plankton both in bays and in the open lake.

Thermocyclops is the name given to a group of forms which, like *Tropocyclops*, are world-wide in their distribution. Fifteen species are recorded from Africa in a survey by Lindberg (1951b). In Lake Victoria the following forms or species have been listed :—

Thermocyclops neglectus Sars : This is a widely spread species in Africa and is a regular member of the plankton in bays and in the open lake.

Thermocyclops emini Mrazek : No doubt can exist about the validity of this remarkable species, which was first described from Lake Victoria by Mrazek (1893) and later found in many African waters. In Lake Victoria this is a true planktonic species.

Thermocyclops schuurmanae (Kiefer) : Some doubts exist regarding the validity of this species.

Cyclops oithonoides Sars : Found by Mrazek, which was allocated by Sars to his *C. neglectus ; C. oithonodes* Sars found by Daday (1910) may be the same as that of Mrazek ; the European " *oithonoides* " form does not appear in Africa.

Diaptomus galeboides Sars : This is the name given as *nom. nov.* by Sars (1909) to the species described by Mrazek as *D. galebi* Barrois. Daday also lists *D. galebi,* but both authors mention several differences from the typical *galebi.* Sars (1909) says that this is a " characteristic plankton form " of the lake. He goes on " together with the usual form, there also occurred in the same sample a much smaller variety of somewhat more slender body and with the anterior antennae more elongated, but otherwise agreeing in all structural details exactly with the larger form ". Both species are treated as one in Table I.

D. stuhlmanni Mrazek : This species was described by Mrazek from the plankton of Lake Victoria, and confirmed by all other observers. Sars (1909) added some morphological remarks and found it numerous in two stations in the lake. Together with the previous species they form a very considerable proportion of the zooplankton of the lake.

The typical *D. galebi* Barr. was noted by several of the earlier observers, but erroneously ; it is a very important member of the zooplankton in the Nile from Egypt to the southern Sudan.

This completes the list of Entomostraca which form the crustacean plankton of Lake Victoria. The decapod *Caridina nilotica* has also been noted by several authors as a constituent of the plankton.

Observations on the horizontal differentiation of crustacean plankton

Observations of previous authors indicated differences in the composition of the plankton at various stations in the lake, but only Worthington gives a table of percentage occurrence of components at one station. In order to contribute to the problem, 10 net samples from various points of the lake were examined by a uniform method. Eight of the samples came from a collection which Dr. Lind (Makerere College) studied for its phytoplankton. These were collected in 1950 ; two samples were collected during the author's stay at Jinja.

Stations are :—

1. Pilkington Bay	16.4.1956	2. Njoga Sesse	14.12.1950
3. Bukoba	4.8.1950	4. Mwanza	5. 8.1950
5. Musoma	6.8.1950	6. Busungwe	4. 8.1950
7. Bukata	3.8.1950	8. Kisumu	7. 8.1950
9. Kisumu	8.8.1950	10. Open lake (north western corner)	26. 4.1956

Seven of these samples were taken with a phytoplankton net, during a circular tour round the lake from Entebbe to Kisumu (3-8 August, 1950) ; some of them were shallow water stations as seen in the admixture of shore, bottom forms and sediments. Only one of the 10 samples is from the open lake. The 10 samples mentioned above were mostly surface hauls and are consequently not as representative of the true composition as the material collected by Worthington.

Each sample was poured into a Petri dish and 3 x 100 specimens of Entomostraca counted at random, excluding nauplii ; within the 100 specimens each species was noted down separately. Finally the percentage occurrence of each species at each station is given in Table I.

Conclusions from this comparative table can only be drawn with some reservations. The material is not uniform either in the method of collecting or in the time of collection.

1. Numerically, copepods prevail over Cladocera ; in all analysed samples they range from 50-96% in stations near the shore ; cyclopids are more numerous than diaptomids. In open water stations, the numbers of diaptomids are equal to or even greater than the cyclopids.

2. The Cladocera seem to increase numerically in proportion to the other members in the more open stations, where conditions apparently allow for the existence of a true plankton association. Bukakata, Busungwe, Pilkington Bay and the open lake station have 28-37% of Cladocera, which agrees well with Worthington's 39%. Apparently, inshore and shallow water stations show a decrease of planktonic Cladocera. Njoga (Sesse), Bukoba, Mwanza, Musoma and Kisumu show only 3-12%, and the number of species participating is smaller.

Some observations made on the food of two cyclopids, Mesocyclops leuckarti and *Thermocyclops neglectus*

Out of twenty *Mesocyclops leuckarti* examined, five had no animal remains in their gut and one had no recognisable remains at all ; chitin fragments from copepods and Cladocera were found in nine and two contained rotifers. Of these eleven specimens, three had an admixture of algal food. Algae only were seen in three specimens. The twenty specimens included both sexes and large juveniles.

Twenty *Thermocyclops neglectus* contained no distinguishable animal remains ; empty *Melosira* frustules could be seen in three specimens ; otherwise a very fine mush, with traces of minute algae and fine filaments were observed.

Remarks on future work

No quantative assessment of zooplankton has been made in the lake and we do not know anything about the horizontal distribution. The food relations of the various components should be investigated. It may be mentioned that an incidental observation on the phyoplankton mass recovered from the stomach of a *Tilapia esculenta* from Pilkington Bay showed, in two slide-smears, over 50 crustaceans, mostly juvenile cyclopids, all in a digested state. These smears represented an insignificant part of the whole stomach contents and it can be deduced that crustaceans add considerably to the diet of this important fish.

Problems, such as morphological variability, sexual processes in the Cladocera and cycles of seasonal appearance need to be investigated.

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Table 1 Percentage composition of Crustacean plankton in Lake Victoria

Species	Njoga Sesse	Bukakata	Busungwe	Bukoba	Mwanza	Musoma	Kisumu (a)	Kisumu (b)	Piik. Bay	Open lake
Diaphanosoma excisum	—	3.0	0.4	—	0.3	1.0	—	1.0	3.3	4.7
Ceriodaphnia cornuta	—	9.0	1.0	—	1.0	—	2.0	—	2.0	8.0
Ceriodaphnia dubia	—	—	0.7	—	1.3	—	—	—	—	3.6
Moina dubia	1.3	1.7	0.3	—	—	1.0	—	1.0	26.7	5.0
Daphnia longispina	—	0.3	—	—	0.3	—	—	—	—	5.0
Daphnia lumholtzi	—	—	—	—	—	—	—	—	0.4	—
Chydorus sphaericus	—	18.3	18.7	12.6	3.4	0.3	—	—	1.0	2.7
Bosmina longirostris	1.3	4.7	7.3	—	0.3	1.7	2.0	1.0	1.6	1.0
Simosa vetulus	4.7	—	—	—	—	—	—	—	—	—
Total Cladocera	7.3	37.0	28.4	12.6	6.6	4.0	4.0	3.0	25.0	30.0
Tropocyclops confinis)?)	—	1.0	3.7	8.6	5.0	39.6	2.0	12.0	8.4	—
Mesocyclops leuckarti	42.7	5.0	0 6	4.6	5.6	8.0	—	—	3.9	11.7
Thermocyclops neglectus & schurmaanae	34.3	5.0	0.3	—	11.0	4.4	1.0	2.0	2.3	17.0
Thermocyclops emini	—	7.0	17.7	—	16.4	3.0	—	—	4.3	5.0
Cyclops juv. sp. indet.	—	27.3	39,7	68.0	24.7	37.6	89.0	79.0	12.4	11.3
Total Cyclopida	77.0	45.	62.0	81.2	62.7	92.6	92.0	93.0	31.3	45.0
Diaptomus galeboides & stuhlmanni	1.0	17.7	9.6	4.2	30.3	3.4	2.0	4.0	33.0	25.0
Total Diaptomida	1.0	17.7	9.6	4.2	30.3	3.4	2.0	4.0	33.0	25.0

The figures above indicate that among the number of organisms counted the particular species occurred in the percentage given. The negative sign (–) indicates that the particular organism was not found but does not mean that it was totally absent ; the representation is only approximate and relative.

APPENDIX 'E'

EFFECTS OF D.D.T. ON THE FEEDING HABITS OF INSECTIVOROUS FISHES IN THE VICTORIA NILE

by P. S. Corbet

As an extension of the general work on fish food, a special study was made of the effects on certain river fishes of the recent treatment of the Victori Nile at Jinja with D.D.T. in order to control populations of larval *Simulium damnosum.* Both before and after the treatment, the sluice gates of the Owen Falls Dam were partially closed on several occasions, and the resulting fall in river level made it possible to collect large numbers of fishes which would otherwise have been inaccessible. Studies of the invertebrate fauna were also made at the same time.

After the first application of D.D.T. there was an abrupt disappearance of lithophilic Trichoptera and Ephemertera. Filter-feeding species of the latter group—such as *Tricorythus tinctus* Kimmins being particularly affected. Since larvae of these two groups had previously formed the most important food of several species of fishes, the indirect effects of the D.D.T. on these fishes were considerable. In general it was found that fishes responded in one of three ways.

(1) A species of *Clariallabes*, which lived amongst the stones of the river bed, showed itself very adaptable when deprived of its main food. On different occasions subsequent to the D.D.T. treatment, plant material, chironomid larvae, copepods and tipulid larvae, were found to constitute their main food. In fact, it appeared that *Clariallabes* was able to utilise a wide range of foods that happened to be available at that time. Since D.D.T., at the particular concentrations used is selective in its effect on invertebrates, fishes of this type are not likely to be seriously affected by such *Simulium* control measures.

(2) Two species of Mormyridae, *Mormyrus kannume* and *Gnathonemus longibarbis*, had previously obtained food from sheltered marginal swamps and also from amongst the stones of the river bed. Their response was simply to obtain all their food from the marginal swamps, these being sufficiently isolated from the main river for the insects living in them to be protected from the full effects of the insecticide.

(3) *Mastacembelus victoriae* had previously shown feeding-habits very similar to those of *Clariallabes*, but it proved far less adaptable. After the D. D. T. treatment, only a few individuals could be collected and an unusually high proportion of these were without food in the stomach. The few which contained food had been feeding on leeches, an unusual element in their food but one which was very little affected by the D.D.T. It is difficult to avoid the conclusion, therefore, that many *M. victoriae* must have either starved or left the locality.

Four months after the first application of D.D.T., and about two months after the last, most of the affected species of insects were again breeding in the river, and the feeding habits of the fishes were slowly returning to normal. There can be little doubt that the insects recolonising the site derived from populations breeding at the Ripon Falls, above the Owen Falls Dam.

Simulium control in small headstreams over a wide area in Uganda is planned by the Uganda Medical Department; it may be important, therefore, to bear in mind the effects such steps may have on the vertebrate as well as the invertebrate fauna of such habitats. A detailed account of this work will be publishod.

APPENDIX F

RING FORMATION IN THE SCALES OF *TILAPIA ESCULENTA*

by D. J. Garrod

It should perhaps be pointed out that ring formation under tropical conditions is different from that occurring in fishes living in temperate waters, where rings are formed as a consequence of the difference between the winter and summer growth rates. In Appendix 'C' to E.A.F.R.O's Annual Report for 1954/55, Holden gave an account of ring formation on the scales of *Tilapia.* He described how the circuli on these scales might be either complete or broken. A circulus which was irregular over the whole of its arc was defined as a ring. A ring might be composed of one or more of these irregular circuli.

Holden demonstrated conclusively that ring formation in mature fish was associated with spawning and also showed that, particularly in *Tilapia esculenta*, ring formation might also occur in immature fish. He put forward the hypothesis that ring formation was caused by a loss in condition. There would seem to be no reason to doubt the validity of this hypothesis, but Holden's assumption that a linear relationship obtains between the size of the scale and the length of the fish is not quite adequate.

An analysis of scales from juvenile *T. esculenta* has shown that the graphical relationship between the size of the scale and the length of the fish is a curve. The difference between the linear and the curved relationship is slight in fish over eighteen centimetres in length, but becomes progressively more significant in smaller fish. Thus Holden's calculations from scale readings of the length of fish are subject to an error, which becomes considerable when estimating their length during early stages in their life histories. For example, a ring at a distance of one millimetre from the centre of the scale would be laid down when the fish was about 9 cms. long, whereas back calculation based on Holden's linear relationship would indicate the length of the fish as being about 10.8 cms. This correction is a matter of some importance when attempting to relate the formation of 'immature' rings with environmental circumstances obtaining at the time they were formed.

R. H. Lowe-McConnell has shown that populations of juvenile *T. esculenta* leave the water-lily swamps and appear on certain seining beaches ; these populations usually show peak modal sizes of about 5-6 cms, 8-10 cms. and 15 cms.

From scale readings using the curved scale, it has been found that there is a tendency for 'immature' rings to be formed at either 5-6 cms. or 10 cms. Forty-five percent of all *T. esculenta* examined show rings at one or other of these lengths ; 12% showed rings at both lengths and 27% showed no 'immature' rings. The remaining 16% showed rings at lengths which could not be included in either the 5-6 or 10 cm. modes. These data indicate that the change in habitat from the water-lily swamps is associated with a loss in condition.

T. esculenta between 5 and 10 cms. long are believed to grow in Lake Victoria at the rate of approximately 1 cm. per month. Thus it is important to determine accurately the length of fish when the 'immature' rings are formed if estimates on the time spent in the water-lily swamps are to be made.

Holden's finding that ring formation in mature fish is associated with spawning have been confirmed and some additional information obtained. It has been found that the distance between spawning rings on *T. esculenta* is remarkably constant. The usual distance between rings being equivalent to one centimetre of growth in the fish.

The minimum amount of growth put on between rings was found to be 0.4 cms. It thus appears that after spawning these fish require a resting period during which they regain their condition and increase their length by a definite amount. The amount of growth that takes place is not a function of the length of the fish, that is to say, either small or large fish make approximately the same amount of growth measured in terms of length. It follows, however, that if growth between spawning periods were to be measured in terms of weight the larger fish must put on more than the smaller fish.

It is usual to find some breeding fish at all times of the year and so unfortunately it is still not possible to determine with certainty the usual duration of the normal resting period. R. H. Lowe-McConnell has shown, however, that a considerable number of the mature fish in any given area spawn during the rainy season ; these seasons occur over most areas of the lake during the equinoxes ; she has also noted that in the northern part of the lake the highest proportion of breeding fish occurs during the March-April period and in the southern part of the lake the highest proportion of breeding fish occurs during the September-October period. There is thus an indication that breeding by individual fish may frequently occur at intervals of six months.

Although it appears that the normal duration of the resting period is such that one centimetre of growth may be made there are a significant number of examples where the growth made between spawning rings is of the order of two centimetres. This may be due to these particular fish prolonging their resting period to twice the usual length.

Marking experiments, indicate that fish over 26 cms. long may grow from two to three centimetres a year.

After considering all the evidence available it seems permissible to put forward the following tentative conclusions :—

(i) Many *T. esculenta* breed twice a year.

(ii) Some probably breed only once a year.

(iii) Between periods of spawning their growth rate is such that they usually increase in length by either one or two centimetres.

These conclusions are in general agreement with the independent estimate derived from marking experiments that *T. esculenta* during the first few years after reaching sexual maturity may grow from two to three centimetres a year.

APPENDIX G

PRELIMINARY NOTE ON INVESTIGATIONS BEING UNDERTAKEN ON THE PHYSIOLOGY OF REPRODUCTION IN FISHES

by A. J. Marshall

Dept. of Zoology and Comparative Anatomy Barts. Medical College, University of London.

Previously unsuspected cyclical changes in the endocrine components of the male gonad of the pike were recently determined in London. The techniques evolved provide a tool for the determination of the precise secretory phases occurring during the sexual cycle of fishes and are now being used to study the periodicity of such seasonal breeders as *Clarias*, *Schilbe* and *Labeo*. The same techniques can be used to derive useful information from such fishes as *Tilapia* and *Haplochromis*, which appear to breed almost continuously and also from other fishes of undetermined breeding category such as *Protopterus*. The various secretory phases of these species are being compared and correlations made with environmental fluctuations ; thus it may be possible to evaluate the effect of external stimuli in regulating reproduction.

The reproductive cycles of fish-eating cormorants (*Phalacrocorax* spp) are also being studied. It has been shown that, unlike most other species so far investigated in other parts of the world, these voracious fish eaters do not need to " gear " their sexual cycle so that breeding occurs at a particular season when special food for the young is available. Even small unfledged cormorants can ingest whole fish almost as long as their own bodies, so these young birds can be reared at any time of the year.

A simple method for restricting the breeding of cormorants has been found and could be put into operation should it be considered desirable to deplete the populations of these birds as an aid to fish conservation.

A subsiduary study on the effect of photofluctuations on the reproductive cycle of a number of vertebrates is also being carried out, with the assistance of a grant from the Royal Society.

All the endocrine material concerned with the above investigations is being sent to St. Bartholomews Medical College, London, where it is being worked out with technical facilities provided by that institution.

Partly based on material collected at Jinja, the discovery has recently been made that in certain fishes Leydig cells are absent from the interstitium of the gonads and that their function, which is to produce the sex hormone, testosterone, is taken over by a homologous structure which arises within the lobule boundaries. The distribution of these alternative glandulars tructures may prove an additional means for determining taxonomic affinities between certain groups of fishes.

Publication

Marshall, A. J. and Lofts, B. The Leydig-cell homologue in certain Teleost fishes. *Nature*, **177**, 704. (1956).

APPENDIX H

RESULTS OBTAINED FROM A SPECTROGRAPHICAL ANALYSIS OF BOTTOM DEPOSITS FROM PILKINGTON BAY

by C. T. Chamberlain

E.A. Agriculture & Forestry Research Organization

Calcium	0.23%	
Magnesium	0.04%	
Sodium	0.45%	
Aluminium	13.1%	
Iron	1.28%	
Copper	100	p.p.m.
Manganese	72	,,
Strontium	37	,,
Barium	77	
Beryllium	1	,,
Chromium	24	,,
Cobalt	5	,,
Gallium	5	,,
Lead	5	,,
Molybdenum	3	,,
Silver	1	,,
Tin	5	,,
Titanium	2220	,,
Vanadium	47	,,
Zinc	100	,,

All the above values are based on the dry weight of the sample.